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GB 2367511 A GB 2367510 A  
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(54) Abstract Title: Valve closure for a cyclone

(57) A vacuum cleaner includes multiple cyclones arranged in series. An upstream cyclone 20, 22 is associated with a particle collection bin 32 which is removable for emptying. A second downstream cyclone 40 is arranged such that in operation, particles are collected in the lower frusto-conical region 38. The lower end of the second cyclone 40 is further associated with a valve mechanism such that in operation the valve is closed and when not in use, the valve opens to allow accumulated particles to pass into the first particle collecting bin 32. In use, air flows through the device and causes an uplift of hemispherical skirt 79. This forces the skirt to engage with O-ring 91 and form a seal. If the air inlet to the device is lowered, then a resultant increase in suction force within the device causes the skirt 79 to move upwards further such that it causes deformation of a resiliently deformable section. Ideally, the O-ring itself is resiliently deformable, but is also mounted on a seating (95, figure 2) which is also formed of resiliently deformable material. Such construction allows the valve to be more efficiently closed, leading to better separation of solids from the air stream.

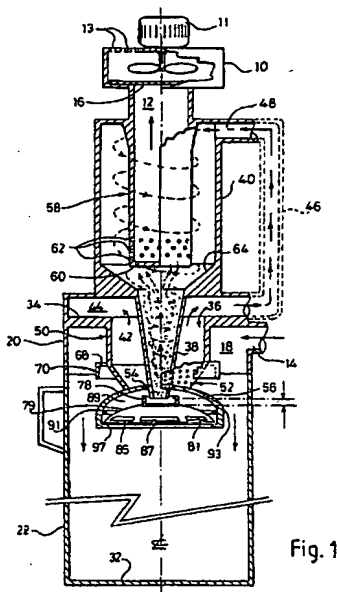
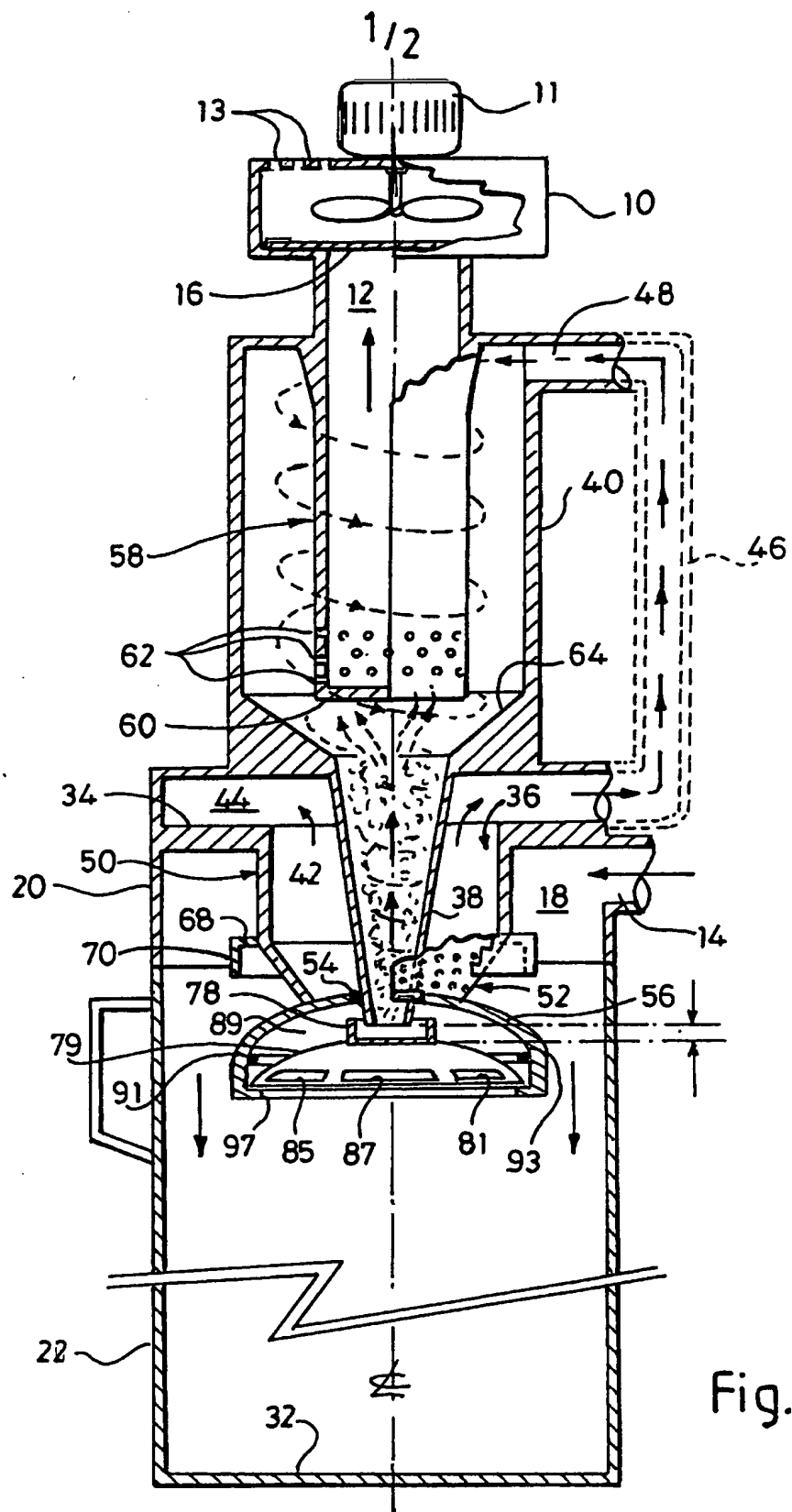


Fig. 1

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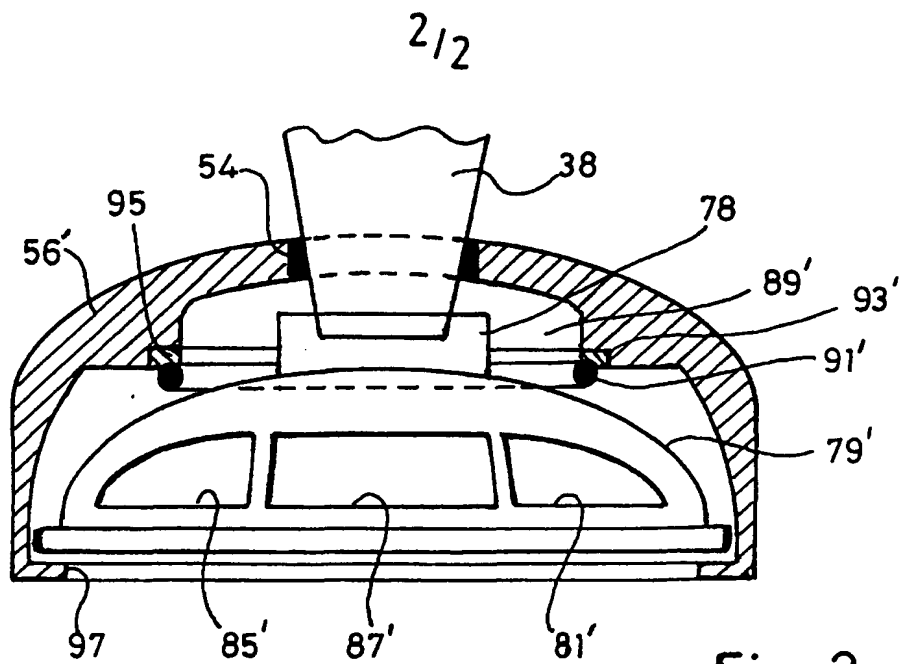


Fig. 2

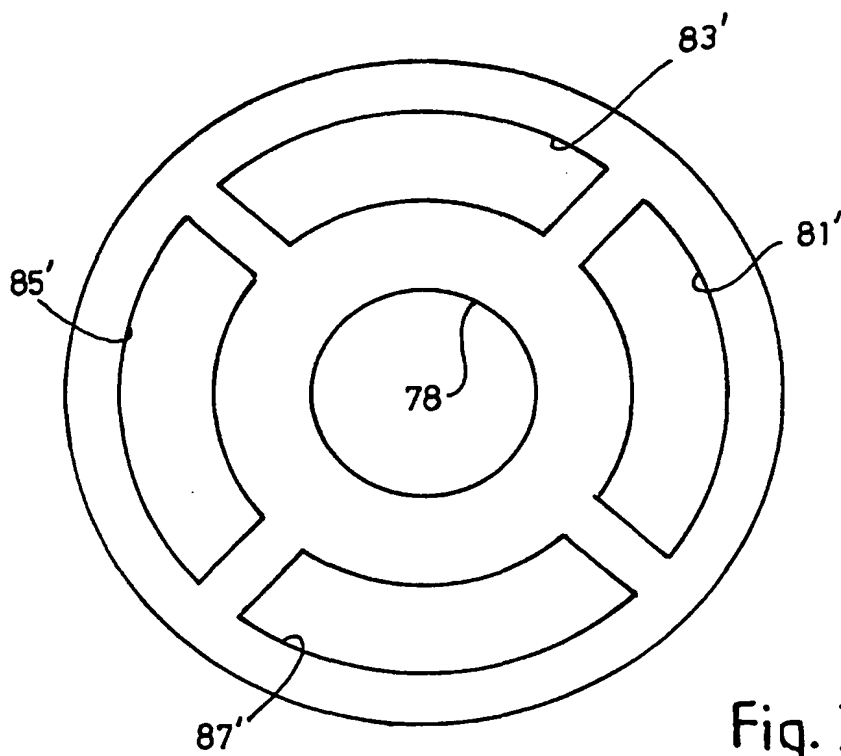


Fig. 3

Title: Improved air/particle separation apparatus and method

Field of invention

This invention concerns air/particle separators in which the separation is largely achieved by centrifugal force acting on a circulating airflow forming at least one cyclone. The particles may be solid and dry such as dust and dirt particles or liquid droplets.

Background

Multiple cyclone separation units are described in GB 2,367,774A and this invention is an improvement in and to the separation unit such as is shown in Figs 3 and 4 of that Specification.

In that unit a temporary particle collection chamber is formed by housing 45 (shown in Fig 4) and valve closure 74 and O-ring seal 82. As described, when the motor driving the suction fan in 10 (Fig 3) is first switched on, the surge of air through the unit from the particle laden air inlet 14, causes the valve closure 74 to rise up and engage the O-ring seal 82 to block off the passage of air from below 74 to the space above it. This forces the incoming airstream to follow the more tortuous path through the unit via particle collecting bin, the openings 54 in the central shell 52, through 46 to the upper end of chamber 40 containing the central vortex starter 58' and after circulating down through regions defined by frusto-conical walls 64, 38 and depositing any remaining particles in the temporary collection chamber within 45, to spiral upwardly to leave via openings 62 and pass through a filter 16 to the suction fan unit 10 and thence to exit as particle free air.

As described with reference to Fig 4 a cylindrical cup 78 is mounted at the upper end of the spigot 76 carrying the closure 74 and the generally flat base of the cup is moved by the

initial upward movement of the closure 74, so as to be a set distance below the open end of the tapering (frusto-conical) cyclone chamber 38. The distance is fixed during manufacture so as to provide the desired particle separation from the airstream and this is typically of the order of a few millimetres.

Efficiency of separation is typically measured by introducing a known weight and volume of fine dry powder such as Kaolin into otherwise clean air entering the inlet 14 and after all the powder has been drawn into the apparatus, and the airflow has reverted to clean air again, the suction fan is stopped and the apparatus is carefully dismantled and the powder found in items 22, 45, 38 and 64 and 16 is recovered and weighed.

The sum of the weights of powder should equal the weight of powder introduced into the inlet 14, and if the recovery of the powder from within the apparatus and the filter 16 is carefully performed, this is found to be the case.

Experiment allows the gap between the lower end of 38 and the base of the cup 78 to be determined so that minimal quantities of powder will be found in the final filter 16. Typical results for apparatus designed and constructed along the lines of that shown in Figs 3 and 4 of GB 2,367,774 when the inlet 14 has a diameter of the order of 31.6mm, the gap between 38 and 78 is 8mm, and the airflow through the fan (in 10) is between 40 and 42 litres/second, have been as follows:-

- weight of powder charge – 200gm
- weight of powder in filter 16 – less than 1gm

The efficiency of the cyclone separation can thus be said to be better than 99.5% (given that less than 1gm of the 200gm of Kaolin has not been separated from the airflow before the latter reaches the final filter 16). Typically 0.7gm has been found in the above example, giving an efficiency of 99.7%

However if the apparatus forms part of a vacuum cleaner, the inlet nozzle is often pushed into a corner where wall meets floor, or when cleaning soft furnishings may be pressed firmly into contact with the material stretched over the cushions or seats and backs of the furniture. In doing so, the air inlet becomes partially obstructed and the volume of air flowing per second through the apparatus, (or its velocity) may be affected.

Experiments have revealed that if the inlet orifice is reduced so as to correspond to an opening of 18mm diameter instead of 31.6mm, all other parameters remaining the same, the weight of Kaolin powder found in the final filter 16 was greater -typically of the order of 2gm. Thus the efficiency had dropped from 99.7% to 99%. Put another way the life of the filter 16 would be reduced by a factor of 3 or more. That is the filter would have to be replaced three times more often for any given usage of the vacuum cleaner, than if the inlet opening remained full bore for the whole of the time the vacuum cleaner was being used.

It is one object of cyclone separating vacuum cleaners to reduce the need to purchase consumables such as bags and filters. However in a domestic situation, in particular, the mode of operation of a vacuum cleaner is such that the nozzle is more often than not buried in carpet or soft furnishings or is used in confined spaces such as between skirting and the floor. Alternatively the normal full bore nozzle is often replaced by a narrow nozzle to allow it to enter crevices between cushions in furniture or car seats, or to enable places to be reached which have restricted access such as below furniture or below or between car seats and fixed parts of a vehicle interior.

In consequence, in practice a domestic vacuum cleaner incorporating cyclone separation and constructed such as described in GB 2,367,774 will typically not operate at its highest theoretical efficiency for much of the time it is drawing in dirt laden air. Indeed, whilst the nozzle is not seeking out dirt and dust, only clean air will be drawn into the inlet nozzle, and it is therefore unlikely that such a vacuum cleaner will ever operate at its theoretical maximum efficiency when actually being used to pick up dust and dirt from carpets, soft furnishings and the like.

It is an object of the present invention to provide a modification to apparatus such as described in GB 2,367,774 with reference to Figs 3 and 4 therein (hereinafter referred to as apparatus of the type described) so as to overcome this.

#### Summary of the invention

In accordance with the present invention in apparatus of the type described the valve closure is adapted to not only move in a direction to make sealing contact with a valve seat to create a closed chamber in which particles will collect during use, but is also adapted to move further in the same direction after sealing engagement has been effected, under the influence of increased suction created by restriction of the inlet to the apparatus, so as to reduce the gap between the downstream end of the frusto-conical cyclone chamber and the closure or a member carried by the closure, in response to said increased suction.

The additional movement of the closure may be effected by constructing the O-ring seal which effects the sealing engagement, from resiliently crushable material, so that a good airtight seal is effected by the initial contact between the seal and the closure (or seal and valve seating), and if the suction force acting on the closure increases further movement of the closure is possible to the extent to which the material forming the seal will collapse, the resilience of the seal material controlling the extent to which the closure is able to move.

Typically the thickness of the O-ring seal material is selected so as to accommodate the desired movement before it becomes incompressible.

Alternatively a thinner rubber O-ring seal may be located on a resiliently deformable support or backing ring which is sandwiched between the O-ring and an annular seating in the wall of the chamber which is to be closed by the movement of the closure into contact with the O-ring, so that the movement (after closure) is substantially accommodated by a compression of the support ring.

Preferably the resilience of the seal material or its support or backing, and the thickness of the material forming the seal (or the support or backing) is selected so as to provide a particular resistance to movement of the closure, such that as the suction force increases so the gap between the end of the cyclone chamber and the closure (or a member carried thereon) reduces to an extent which at least in part compensates for the reduced separation efficiency of the apparatus when acting under the changed airflow due to the partial blocking of the inlet nozzle.

In a further arrangement the O-ring seal may be carried by a rigid annular support and a resiliently deformable member such as a layer of rubber or a compression spring is sandwiched between the support and the wall of the chamber.

In the foregoing the O-ring has been assumed to be carried by the stationary housing shell within which the closure is located and moves. However it is to be understood that the seal (and any crushable support or backing) may be carried by the closure or the crushable material may be carried on one part and the O-ring on the other.

According to another aspect of the invention a method of improving separation efficiency of a cyclone based air-particle separation apparatus of the type described in which a plate is spaced from the downstream open end of a frusto-conical cyclone separation chamber, comprises the step of moving the plate towards the said open end of the separation chamber in response to an increase in suction force brought about by a partial or almost complete blockage of the inlet to the separation apparatus, so as to control the size of the gap in response to variations in the suction force acting on the closure due to the partial or almost complete blockage of the inlet to the apparatus whilst in use.

Typically the method is achieved by resiliently supporting the closure in a valve-closed state, the force needed to overcome the resilience and to permit movement of the closure towards the cyclone chamber in relation to the force exerted on the closure due to increased suction, determining the distance through which the closure will move in response to any particular reduction in the bore of the inlet.

Preferably the resilient support is such as to permit a progressive movement of the closure in response to increasing suction force and vice versa.

Preferably the resilience is provided by the resilience of material from which the seal is formed or from material or a device such as a spring between the seal and the wall of the chamber.

In a further arrangement movement of the closure member towards a valve seating is designed to sandwich an O-ring between the closure and the seating and having formed a seal thereby, and the distance through which the closure can move in the same direction as it has to move to create the seal after the seal has been made, is constrained by a resiliently deformable means sandwiched between the O-ring and a fixed member.

In one embodiment of this further arrangement the resiliently deformable member comprises spring means which is compressed by movement of the closure in the said direction.

In another embodiment of this further arrangement the resiliently deformable member comprises spring means which is elongated by movement of the closure in the said direction.

Although the closure has been described as moving into contact with an O-ring seal, it is to be understood that the seal may be carried by the closure and the inside of the chamber is adapted by means of an internal annular rim to provide an annular seating with which the seal is brought into contact by movement of the closure under the suction force and either the seal is resiliently deformable or the seating is resiliently deformable, or resiliently displaceable relative to the chamber, or a resiliently deformable member is sandwiched between the seal and the seating, to provide for resilient movement of the closure towards the open downstream end of the cyclone separation chamber under an increased suction effect occasioned by partial or almost complete blockage of the inlet to the apparatus.

In an experiment in which the effective inlet area was reduced from one of 31.6mm diameter to one of 18mm diameter, the corresponding reduction in the gap between the closure (or member carried by the closure) and the cyclone chamber was of the order of 1mm, and this was found to reduce the weight of Kaolin which reached the final filter to approximately 1.3gm. This will almost double the life of the final filter as compared with an apparatus in which the gap remained constant.

The invention also lies in a vacuum cleaner incorporating cyclone separation apparatus as aforesaid and including means by which the closure, in response to increasing suction, is resiliently moveable towards a frusto-conical cyclone separation chamber to compensate for airflow variation due to at least a partial blockage of the air inlet to the vacuum cleaner.

In separation apparatus embodying the invention movement of the closure after making sealing contact to close the chamber is preferably in the range 1-3mm, thereby decreasing the gap from a typical 8mm, to 7mm, 6mm or 5mm respectively, in response to increasing restriction of the inlet.

The invention will now be described by way of example with reference to the accompanying drawings in which:-

Fig 1 is an elevation partly in cross-section of a cyclone separation apparatus embodying the invention,

Fig 2 is a similar view to an enlarged scale of the valve closure and dust collection chamber of the apparatus of Fig 1, and

Fig 3 is a plan view from above of the closure device of Fig 2.

Fig 1 largely corresponds to Fig 3 of the drawings accompanying GB 2,367,774 and in turn that is similar to part of the arrangement shown in Figs 1 and 2 of that Specification.

Referring to Fig 1 of the present Application a fan or turbine 10 driven by a motor 11 provides a source of suction at the upper end of passage 12 to draw air through the different stages of the apparatus, as will be described, from an inlet passage 14.

In the case of a domestic or commercial vacuum cleaner 14 will be connected to a hose (not shown) having a dust collecting head of known design (not shown) at its far end. The last part of the hose may in known manner be rigid.

In the case of a device for separating particles from air from apparatus such as in a laboratory or industrial or commercial environment, the inlet 14 will be connected to the enclosure from which dust/particle laden air is to be extracted.

A filter 16 (which may be removable for cleaning or replacement) is located immediately prior to the suction source 10.

The inlet passage 14 introduces air into the upper end 18 of a two part cylindrical chamber 20, 22, sealingly joined at 24 but separable to allow particles collected from the airstream to be emptied.

Particles separated out by a first separation step (which occurs within 20, 22) are collected in the lower end of 22.

To this end the upper end of 20 is closed at 34 but includes a central circular opening 36 through which a frusto-conical extension 38 of a cylindrical chamber 40 forming part of a second separation stage can pass in a downward manner. An annular space 42 between the wall of the opening 36 and the extension 38 allows air to leave 20, 22 and pass into an annular manifold 44 from which it can pass via a passage (shown dotted at 46) to an inlet port 48 at the upper end of the chamber 40.

Inlet 48 introduces air into the interior of 40 in a tangential manner in a similar way to that in which 14 introduces air into the region at the upper end of 20, 22.

The first separation step occurs at the upper end of 20, 22 in which a collar 50 extends centrally of 18 axially down into 20. The interior of the collar communicates with the opening 36 in the end 34 of 20. The collar is generally cylindrical and terminates in a frusto-conical shell 52 which extends down to and is sealed to the frusto-conical extension 38, where it is sealingly joined at 54. A shell 56 which is generally part hemispherical and open at its lower end, extends from the join 54.

The shell 52 is perforated by a large number of very small holes 53. The skirt is non-perforated.

The shell 52 may alternatively be part hemispherical as shown in Fig 3 of GB 2,367,774.

In operation, the incoming tangential rush of air through 18 sets up a rotating mass of air around 50 which can only exit via holes 53, which are axially displaced from the region into which the air is introduced. The rotating mass of air migrates axially as it rotates, so setting up a so-called vortex flow within 20, 22 and heavier than air particles will be flung towards the cylindrical wall of the chamber 20. The particles will axially migrate with the vortex and once in a downwardly spiralling trajectory will tend to continue in that manner axially down the chamber 20, 22 through the annular gap between the skirt 56 and the interior of 22, rather than exiting through the holes 53.

Once the particles are below the skirt 56, there is little tendency for them to migrate back up the chamber, even if turbulence exists below the skirt, and they will tend to congregate in the lower region of 22.

Thus although air entering at 18 may be laden with heavier than air particles (dust, hairs, grit and the like in the case of a vacuum cleaner), most of these particles will have been

separated from the air before it passes through the openings 53 in the shell 52. Therefore the air passing up through 42 and via 44, 46 and 48 into the upper end of the second separation stage, will be substantially depleted of particles, relative to that entering at 14.

As mentioned earlier, suction is applied to the upper end of passage 12, which is formed by a hollow generally cylindrical housing 58 which extends axially of the cylindrical chamber 40 to terminate near its lower end.

The lower end of housing 58 is closed at 60 but around that closed end, the wall of 58 is perforated with a large number of small holes 62, so that suction applied at 12 will cause air from within 40 to be sucked into the interior of 58 to pass axially therethrough in an upward sense.

It is this suction which causes air to be drawn in through 48 from 44 so establishing the airflow through the chambers from inlet 14. The suction device includes outlets 13 through which air, now devoid of particles, can exit to atmosphere.

The external surface of the upper end of housing 58 is frusto-conical, and in combination with the tangential inflow of air, creates a rotating mass of air around the housing 58, which, since it must spiral axially down the housing 40 before it can leave via holes 62, becomes a vortex which accelerates as it reaches the lower end of the cylindrical region of 40 due to a sudden frusto-conical reduction in the internal cross-section of 40, as denoted by 64. The acceleration increases the centrifugal forces on any heavier than air particles relative to the air molecules, so causing any such particles to carry on spiralling downwardly accelerating as they do due to the frusto-conical cross-section of the interior of extension 38 of the chamber 40.

By ensuring that the airflow through 40 is high enough, the rotating and axially descending vortex of air substantially bypasses the openings 62 in the wall of 58 and continues to spiral downwards carrying the particles in the spiralling airstream. At some point the rotating mass of air is inverted and begins ascending centrally of the downward spiral of

air to pass up through 38. The sudden deceleration and acceleration of the air molecules as they change direction, will in general be too great for heavier than air particles to remain in the airstream, to follow the same tortuous path as the air does, and such heavier than air particles will become separated from the airstream and travel down through the smaller open end of the frusto-conical chamber 38.

The two stages of separation so achieved, result in substantially all heavier than air particles remaining in 22 or in a small closed intermediate chamber (to be described) at the bottom of 38.

Improved separation can be achieved in the first stage by providing an annular flange 68 around the collar 50 at the junction between the perforated and unperforated wall sections. This serves to accelerate the rotating mass of air just before it reaches the perforated region 52, thereby forcing any heavier than air particles to migrate radially even further from the collar.

The effect is further enhanced by extending the periphery of the flange 68 in an axial manner to form a cylindrical lip 70 which extends in the direction of movement of the vortex in the chamber 20, 22. Typically the diameter of the collar 50 is in the range of 5-8 cm and the radial extent of the flange will be of the order of 1cm and the lip can extend axially from the flange by a similar distance of the order of 1cm.

The separator may be used to separate particles in the form of liquid droplets (such as water droplets) from incoming air containing such droplets. The presence of the flange 68 and lip 70 reduces the risk of liquid droplets from being entrained in the air exiting via holes 52, since they, like any heavier than air particles, will be forced to adopt a high rotational speed to pass around flange 68 and will therefore be even further removed by centrifugal force from the inner regions of the chamber 20, 22.

Fig 2 of GB 2,367,774 illustrates an alternative 2-stage separator in which air flow is established in a similar way as in Fig 1 from inlet 14 to suction device 10, and the same

reference numerals are employed to denote parts which are common to the two arrangements, and in which the frusto-conical extension 38 of housing 40 terminates in a region 43 the lower end of which is formed as a cage 45 for a light weight ball 47, which when airflow is established, is drawn up to close off the lower end of 43.

Fig 3 of GB 2,367,774 illustrates an alternative 2-stage separator similar to Fig 1 of that Specification (to which end the same reference numerals have been employed as appropriate), in which a valve has been incorporated, as in Fig 2 of GB 2,367,774, but in which a different type of valve is shown from that shown in Fig 2 of that earlier Specification. The valve is shown in more detail in Fig 4 of GB 2,367,774, and comprises a conical poppet 74 at the lower end of a spindle 76 at the upper end of which is a cup 78. A valve seating 80 retains an O-ring 82 against which the conical surface of the poppet 74 is forced, to close the valve once airflow has been established through the apparatus. The spindle 76 extends through the poppet and is slidingly received in a guide 82 in a cross member 84 which extends across the open lower end of the housing 45. The cross member 84 and guide 82 are shown in the scrap view of Fig 4A of GB 2,367,774.

Particles can pass down through the open end of tube 38 during operation, and remain above the poppet 74 until airflow ceases, whereupon the poppet drops and particles can fall past the conical surface of the poppet and around the cross member 84, into the common bin 22. A spring (not shown) may be fitted between the conical surface 74 and the upper end of the enclosure 86, (or between the cup 78 and the end 86) so that as soon as airflow drops, the poppet valve opens under the action of the spring.

In the improved intermediate chamber (created when the valve is closed) at the bottom of 38, shown in Figs 1-3 the cup 78 of the valve of Fig 4 of GB 2,367,774 is now carried at the centre of a hemispherical shell 79 the wall of which is apertured at 81, 83, 85 and 87 to allow particles trapped in the cup 78 and in the cavity 89 around cup 78 during operation.

As happens to conical shell 74 of Fig 4 of GB 2,367,774 during operation, the shell 79 is lifted up into contact with an O-ring 91 carried by annular seating 93 within the outer hemispherical shell 56. The latter is sealed to the lower end of 38 by a seal 54 as previously described.

In Fig 1 the openings 81-87 are shown as narrow slits near the lower end of shell 79 and the O-ring seal 91 is shown at the upper end of a generally cylindrical interior region of the shell 79. Upward movement of the shell 79 under suction causes the unperforated central region of shell 79 to engage the seal 91 and form the closed cavity 89 into which particles separated by the cyclone 38 will collect.

When the fan 10 is stopped and suction ceases, the shell 79 drops away allowing particles to fall through the openings 81, 83 etc. into the dust collecting bin 22.

On restarting the fan 10, the initial suction surge may cause particles remaining in cavity 89 to move radially inwardly with the rush of air, but the cylindrical wall of cup 78 will tend to inhibit their progress to the lower open end of 38. Once the shell 79 has closed to the seal 91, there is no further inrush of air and no tendency for particles remaining in 89 to move out of 89 into 38.

Wider openings 81, 83 etc. may be provided in the shell 79, as shown by 81', 83', etc. in the shell 79' of Fig 2. However, since these will reduce the unperforated annular region of the shell between the openings and the cup 78, a smaller diameter seal 91' must now be used, located so as to engage a smaller diameter region of the shell 79' as can be seen by comparing Figs 2 and 3 with Fig 1. To this end the annular seating 93' of shell 79' is nearer the centre of the shell as shown in Fig 2.

In accordance with the present invention the compressibility of O-ring seal 91 (91') is such as to allow limited upward movement of shell 79 (79') after the latter has engaged the O-ring 91 (91'), under the effect of increasing suction as can occur if the inlet 14 becomes restricted in operation.

If insufficient movement in an upward sense can be achieved by compression of the resiliently deformable material from which O-ring 91 (91') is made, then as best seen in Fig 2, the seating for the O-ring may include a ring of resiliently deformable material 95 which as the ring 91' becomes compressed substantially to the point beyond which it will not further compress, the material of ring 95 will begin progressively to compress, and allow the shell 79' to move further in an upward sense.

Movement of the shell 79 (79') in this manner causes the base of cup 78 to move closer to the opening at the lower end of 38, which experiments have revealed, increases the proportion of particles retained in cavity 89 (89') in relation to those which escape into 38 to be collected by the filter 16.

The shape of the cup 78 is not limited to what is shown in Fig 2 but the wall cup may be frusto-conical or may be curved and if curved, the curvature may extend to the base of the cup, converting the cup to an upturned hemisphere.

Although not shown, a compression spring (not shown) may be provided between a ring such as 95 (albeit formed from generally incompressible material such as metal or rigid plastics) and an annular seating in the wall of the shell 56 (56'), and the O-ring may in that event be substantially incompressible other than to conform to the shape of the shell 56 (56') and effect a good seal between it and the shell, and movement of the shell 79 (79') in an upward sense under increasing suction, is governed by the force needed to compress the spring (not shown).

The shells 56 (56') and 79 (79') are preferably plastics mouldings.

As shown in Figs 1 and 2 the lower open end of 56 (56') includes a radially inwardly directed annular flange (or lip) 97 which retains the shell 79 (79') within 56 (56').

Typically shell 79 (79') is resiliently deformable to permit it to be squeezed into a non-circular shape and be pushed into the shell 56 (56') through the open end, during assembly.

Alternatively the annular lip 97 may be a separate annular component which is sprung into place after shell 79 (79') has been placed inside 56 (56').

The position of 56 (56') relative to 38 may be adjustable to allow for a fine adjustment of the gap between the lower open end of 38 and the base of cup 78 when the shell 79 (79') is pushed upwards relative to 56 (56') by a known force, to enable the device to be calibrated, and to allow for manufacturing tolerances to be accommodated.

## CLAIMS

1. Apparatus of the type described wherein a valve closure is adapted to move in a direction to make sealing contact with a valve seat to create a closed chamber at the lower end of a frusto-conical cyclone separation chamber in which particles will collect during use, and wherein the closure is also adapted to move further in the same direction after sealing engagement has been effected, under the influence of increased suction created by restriction of the inlet to the apparatus, thereby to reduce the gap between the downstream end of the frusto-conical cyclone separation chamber and the closure or a member carried by the closure, in response to said increased suction, whilst maintaining the sealed condition.
2. Apparatus as claimed in claim 1 wherein the additional movement of the closure is effected by providing an O-ring seal which is engaged by the closure to effect the sealing engagement, and selecting an O-ring which is formed from resiliently crushable material, so that a good airtight seal is effected by initial contact so that if the suction force acting on the closure increases, further movement of the closure is possible to the extent to which the material forming the seal will crush, the resilience of the seal material controlling the extent to which the closure is able to move.
3. Apparatus as claimed in claim 2 wherein the cross-section of the O-ring seal is selected so that there is at least sufficient crushable material in the cross section to accommodate the desired movement before the seal becomes incompressible.
4. Apparatus as claimed in claim 1 wherein a rubber O-ring seal is located on a resiliently deformable support member which is sandwiched between the O-ring and an annular seating in the wall of the chamber which is to be closed by the movement of the closure into contact with the O-ring, so that after sealing contact has been established,

subsequent movement of the closure is substantially accommodated by a compression of the support member.

5. Apparatus as claimed in claim 4 wherein the support member is a ring.
6. Apparatus as claimed in claim 1 wherein an O-ring seal is carried by a rigid annular support and an annular resiliently deformable member is sandwiched between the rigid support and the wall of the chamber.
7. Apparatus as claimed in any of claims 2 to 6 wherein the resilience of the seal material, or its support member, and the cross-section thickness of the material forming the seal (or the support member) is selected so as to provide a particular resistance to movement of the closure, such that as the suction force increases so the gap between the end of the cyclone chamber and the closure (or a member carried thereon) is reduced to an extent which at least in part compensates for the reduced separation efficiency of the apparatus when operating with the reduced airflow due to the partial blocking of the inlet nozzle.
8. Apparatus as claimed in any of claims 1 to 7 wherein the O-ring seal with or without annular support member is carried by the housing shell within which the closure is located and moves.
9. Apparatus as claimed in any of claims 1 to 7 wherein the O-ring seal with or without annular support member is carried by the closure.
10. Apparatus as claimed in any of claims 1 to 7 wherein the O-ring seal is carried by the closure and an annular crushable member is carried by and forms the valve seating, or vice versa.

11. Apparatus as claimed in any of claims 1 to 10 wherein the additional movement of the closure is controlled at least in part by spring means.
12. A method of improving separation efficiency of a cyclone based air-particle separation apparatus of the type described in which a plate is spaced from an open downstream end of a frusto-conical cyclone separation chamber, comprising the step of moving the plate towards the said open end of the cyclone separation chamber in response to an increase in suction force brought about by a partial blockage of the inlet to the separation apparatus, so as to reduce the size of the gap between the plate and the said open end in response to an increase in the suction force and reduction in air flow due to the partial blockage of the inlet to the apparatus whilst in use.
13. A method as claimed in claim 12 wherein the plate comprises or is carried by a valve closure adapted in use to move towards and sealingly engage a valve seat to create a closed chamber at the lower end of the cyclone separation chamber, and the closure is resiliently supported in the valve-closed state, and the force needed to overcome the resilience and cause the closure to move towards the cyclone chamber relative to the force exerted on the closure due to increased suction, determines the distance through which the closure will move in response to any particular reduction in the area of the inlet to the apparatus due to the partial blockage.
14. A method as claimed in claim 13 wherein the resilience of the support is selected so as to permit a progressive movement of the closure towards the separation chamber in response to increasing suction force and vice versa.
15. A method as claimed in claim 13 wherein movement of the closure member towards the valve seat sandwiches an O-ring seal between the closure and the valve seat to form a seal thereby, and the distance through which the closure subsequently can move in the same direction after the seal has been made, is determined by a resiliently deformable means sandwiched between the O-ring and a fixed member such as the valve seat.

16. A method as claimed in claim 13 wherein the additional movement of the closure after making sealing contact is controlled at least in part by spring means.
17. A method as claimed in any of claims 13 to 16 wherein the O-ring seal is carried by the closure and the inside of the chamber provides an annular seating with which the seal is brought into contact by movement of the closure under the suction force.
18. A method as claimed in claim 17 wherein the seal is resiliently deformable.
19. A method as claimed in claim 17 wherein the seating is resiliently deformable.
20. A method as claimed in claim 17 wherein the seating is resiliently displaceable relative to the chamber.
21. A method as claimed in claim 17 wherein a resiliently deformable member is sandwiched between the seal and the seating, to provide for resilient movement of the closure towards the open downstream end of the cyclone separation chamber under an increased suction effect occasioned by partial or almost complete blockage of the inlet to the apparatus.
22. A vacuum cleaner incorporating cyclone separation apparatus of the type described and further comprising a valve closure which is adapted to move in a direction to make sealing contact with a valve seat to create a closed chamber at the lower end of a frusto-conical cyclone separation chamber to collect particulate material in use, wherein the closure is also adapted in use to move further in the same direction in response to increasing suction, towards the separation chamber to compensate for reduction in airflow due to a partial blockage of the air inlet to the vacuum cleaner, in use.
23. A vacuum cleaner including apparatus as claimed in any of claims 1 to 11.



Application No: GB0322680.0

Examiner: Mr Jason Scott

Claims searched: 1-23

Date of search: 29 March 2004

## Patents Act 1977: Search Report under Section 17

### Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular reference
A	-	GB 2367511 A NORTH, JOHN HERBERT
A	-	GB 2367512 A NORTH, JOHN HERBERT
A	-	WO 98/35601 A1 FRESHMAN AKTIEBOLAG
A	-	GB 2367510 A NORTH, JOHN HERBERT
A	-	WO 98/35603 A1 FRESHMAN AKTIEBOLAG
A	-	GB 2367774 A NORTH, JOHN HERBERT

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### Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC<sup>w</sup> :

Worldwide search of patent documents classified in the following areas of the IPC<sup>07</sup>

The following online and other databases have been used in the preparation of this search report

WPI, JAPIO, EPODOC

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